METHODOLOGY AND CLINICAL VALUE OF TRANSCUTANEOUS BLOOD GAS MEASUREMENTS IN THE FETUS

S. Schmidt

Departement of Obstetrics & Gynecology, University of Bonn,
Sigmund-Freud-Straße 25, D-5300 Bonn, FRG

Summary

Aiming at an improvement of fetal surveillance in high risk cases, a clinical trial was performed to evaluate the potential of fetal $tcPco_2$ monitoring. An electrochemical $tcPco_2$ sensor heated at 44 °C was applied in 119 fetuses after abnormal heart rate patterns had occured. The number of operative deliveries for fetal distress was reduced to 14 cases by means of the biochemical parameters ($tcPco_2$) and fetal blood analysis (FBA). In the majority of cases with pathologic heart rate patterns the $tcPco_2$ values were prepathologic or normal (60 %), while in 68 % of cases with prepathologic heart rate patterns the $tcPco_2$ level was normal. At all instances an intrauterine complication was indicated by a marked rise of the $tcPco_2$ level. The clinical benefit of using the $tcPco_2$ measurement is the better specificity of detecting fetal distress when compared with the use of cardiotocography alone. Furthermore the $tcPco_2$ technique has the advantage of providing continuous information about one biochemical parameter and of avoiding the necess ity of repeated incisions of the scalp, as compared with the technique of fetal blood analysis. In conclusion the use of this non-traumatic technique lends itself to avoid unnecessary operative deliveries in high risk cases.

Keywords: fetal monitoring, transcutaneous measurement, FBA, $tcPco_2$, CTG, fetal distress.

Fetal heart rate monitoring, which is used by the large majority of obstetricians, is of high value as a screening method as it has a high sensitivity but provides a number of false positive results (2,11). By indicating fetal distress which does not acutally exist, it leads to unnecessary operative deliveries, when used as the only method of fetal surveillance. It was the aim of this study to evaluate the potential clinical benefit of the $tcPco_2$ -monitoring during labor, which provides reliable information about one biochemical parameter in the fetus during labour,

to verify fetal distress in cases where an intrauterine complication is indicated by abnormal fetal heart rate patterns (8, 10).

Material and methods

During the course of this study $tcPco_2$ -measurements were performed in 119 fetuses in addition to continuous cardiotocography. Cases were included in the study when either suspect, prepathologic or pathologic heart rate patterns occured in the CTG on admission or during labour. Fetal blood analysis (FBA) was performed when the following cardiotocographic changes were observed: decelerations-variable, late, early (more than 60 bpm) - for more than 10 minutes or 3 contractions, and immediately in cases with severe bradycardia (less than 100 bpm). 85 mothers were para 0, 13 were para I, 21 were para II or more. The patients were given detailed information about the $tcPco_2$ -measurement and informed consent was achieved. 76 infants were born spontaneously, 15 by vacuum extraction, 5 with the help of modified forceps. In 23 cases cesarean section had to be performed.

Operative delivery for fetal distress was performed in 14 cases. The indication for an operative delivery for fetal distress was based on the heart rate pattern, the level of the $tcPco_2$ and the result of the FBA.

The status of the newborns was evaluated with a modified Apgar Score in combination with a biochemical analysis of a sample from the umbilical artery (5). All babies were born in vigorous state ($\geqslant 7$). As the result of pH-measurements in umbilical artery blood (samples collected directly after delivery), we found a value of below 7.20 in 8 cases, a value of 7.20 - 7.29 in 26 cases, while in the rest of the 86 cases, the pH-values were $\geqslant 7.30$.

The $tcPco_2$ -measurement was performed using the modified Severinghaus electrode (Radiometer B 5230), the details of which have been described elsewhere (7, 10). After sterilisation and a two-point-calibration, the electrode was applied onto the fetal scalp and fixed by means of tissue glue. The measuring temperature for this trial was 44° in all cases. Transcutaneous Pco_2 -values were not corrected for the metabolism of the skin and the raised local tissue temperature. The maximal drift which was evaluated by means of a calibration gas was

2 %. The results of the $tcPco_2$ -measurements were entered on the enquiry form together with the findings of the vaginal examination, the result of the concurrent fetal blood analysis, the result of the evaluation of the retrograde cardiotocogram (Hammacher-Score) and the indication for fetal blood analysis (1). Data were fed into a Cyber 70 (Control Data) and evaluated with the Statistic

Package for Social Science (SPSS) of Northwestern University. The linear correlation coefficient, the slope, the intercept and the significance were calculated for the comparison of continuous $tcPco_2$ levels to the blood analysis (FBA) and the pH. In order to plot the mean $tcPco_2$ of the second stage of labour the transcutaneous measurement was scanned at a sampling frequency of ten minutes and compared with the result of the assessment of the newborn. Furthermore, in order to investigate the statistical relationship between the measuring data of the $tcPco_2$ and the result of the semiquantitative evaluation of the Hammacher-Score, the contigency coefficients according to Pearson were calculated. As a basis for this calculation a table of nine fields was drawn up for the chi-square test. The result of the Hammacher-Score (HS) respectively the transcutaneously measured carbon-dioxide-partial-pressure were defined as normal (HS=0-2 respectively $tcPco_2 \leqslant 70$ mmHg), prepathologic (HS=3-7 respectively $tcPco_2 >$ 70-80 mmHg and pathologic (HS $\geqslant$ 8 respectively $tcPco_2 >$ 80 mmHg).

Results

The accuracy ot the $tcPco_2$ technique to measure the Pco_2 of the blood was approved by comparing the Pco_2 values of the fetal blood analysis with the synchronously recorded $tcPco_2$. We found a statistically significant relationship ($r = 0.81$, $p < 0.001$) (Fig. 1). Furthermore the transcutaneous Pco_2 values recorded at the moment of delivery correlated with the Pco_2 values of the umbilical artery ($r = 0{,}76$; $p < 0{,}001$ (Fig 2)). In order to define the prepathologic and pathologic range of $tcPco_2$ we evaluated the relationship between $tcPco_2$ and pH values in the fetal blood (8). The actual pH value was compared with the synchronously recorded $tcPco_2$ value. We found a statistically significant correlation ($p < 0.001$). The correlation coefficient for 44°C was -0.53, the intercept 788.83 and there was a negative slope of -0.99. While there was a considerable scattering of $tcPco_2$ values in the pH range of above 7.25, no preacidosis occured during $tcPco_2$ values of $<$ 70 mmHg and no pH values of $<$ 7.20 were observed with $tcPco_2$ values of $<$ 80 mmHg at 44 ° C. The mean value of the transcutaneous measurement during the second stage of labour was compared with the result of the assessment of the newborn. The $tcPco_2$ level was significantly lower in normacidic newborns when compared with the $tcPco_2$ level in cases with raised acidity respectively acidosis (2a = o0,05) (Fig. 3). Comparing the $tcPco_2$ values with the results of clinical assessment we found that the mean value of cases with an Apgar score of 10 was significantly lower as with an Apgar score of 9 respectively 8 (2a =0,05), (Kruskall-Wallis-Test) (Fig. 4). With the use of a multi-channel-recorder it was possible to provide a continuous poly-

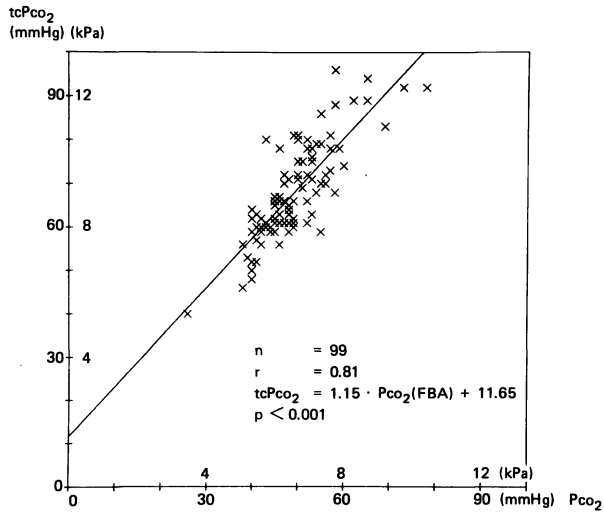

Fig. 1 Correlation between the transcutaneously measured carbon-dioxide-partial-pressure ($tcPco_2$) and the Pco_2 of the fetal blood analysis (FBA): The $tcPco_2$ values measured at 44° are not corrected for the effect of raised temperature nor the Co_2 production of the tissue.

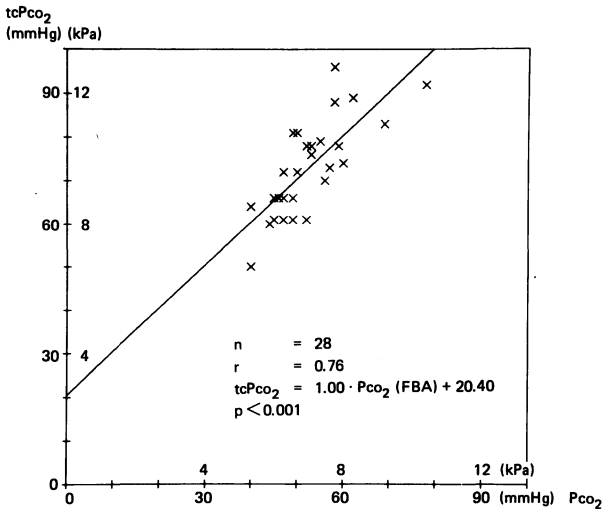

Fig. 2 Correlation between the $tcPco_2$ at the moment of delivery and the Pco_2 measured in a blood sample of the umbilical artery (UA).

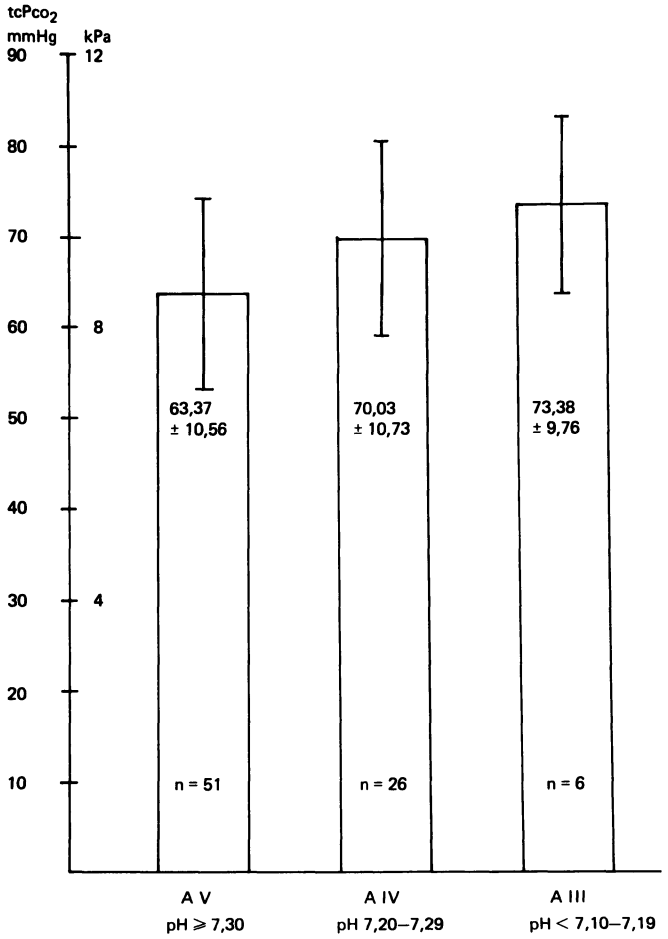

Fig. 3 Mean value and standard deviation of the $tcPco_2$ during the second stage of labour according to the result of the biochemical assessment of the newborn (pH in umbilical artery blood).

graphic recording of both the cardiotocogram and the data of the transcutaneous measurement. Various combinations of heart rate patterns and the level of the transcutaneous Pco_2 were observed (see Fig. 5-7). A suspicious CTG in combination with a normal level of the $tcPco_2$ can be seen in the tracing with the registration number 39/44. During the first stage of labour variable decelerations were observed in the CTG; however the $tcPco_2$ was within the normal range. There was no indication for operative delivery for fetal distress superfluous in this case. After spontaneous delivery the baby was vigorous and normacidic (pH in the umbilical artery 7,25).

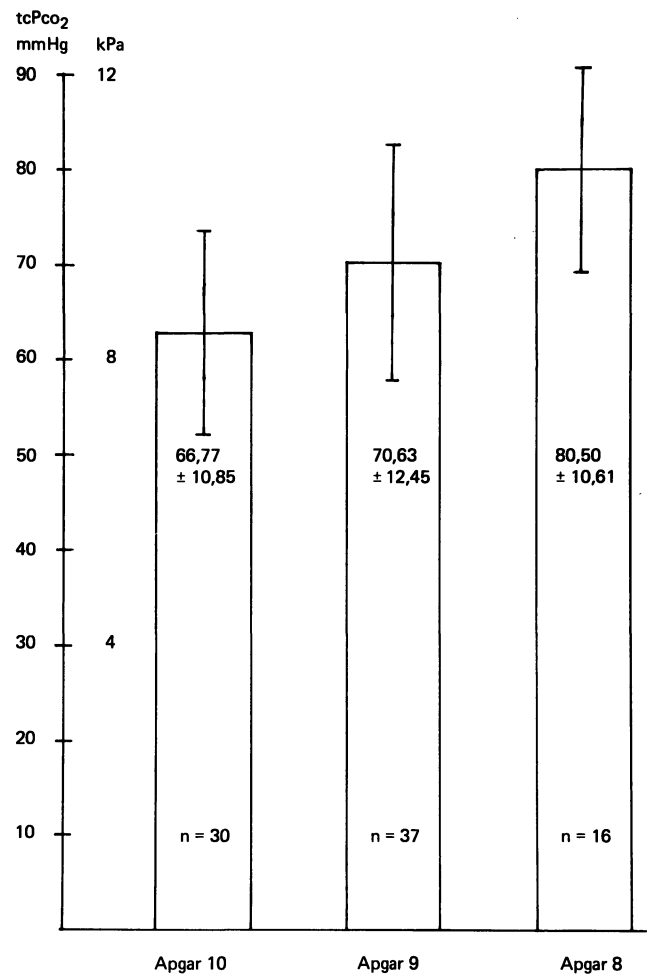

Fig. 4 Mean value and standard deviation of the $tcPco_2$ during the second stage of labour according to the results of the clinical assessment of the newborn (modified Apgar score).

A critical rise of the $tcPco_2$ during pathologic heart rate pattern is demonstrated on Fig. 6 with the registration number 11/44. The baby was born by immediate cesarean section after the intrauterine complication had been verified by FBA. Due to the clear indication of fetal distress by means of the $tcPco_2$ -tracing it was possible to perform the obstetrical intervention right on time. In spite of acidosis (pH UA $<$ 7,20), the baby was delivered before signs of clinical depression had been manifested. The polygraphic tracing shown in Fig. 7 (registration number 10/44) demonstrates how a fast progressing intrauterine complication

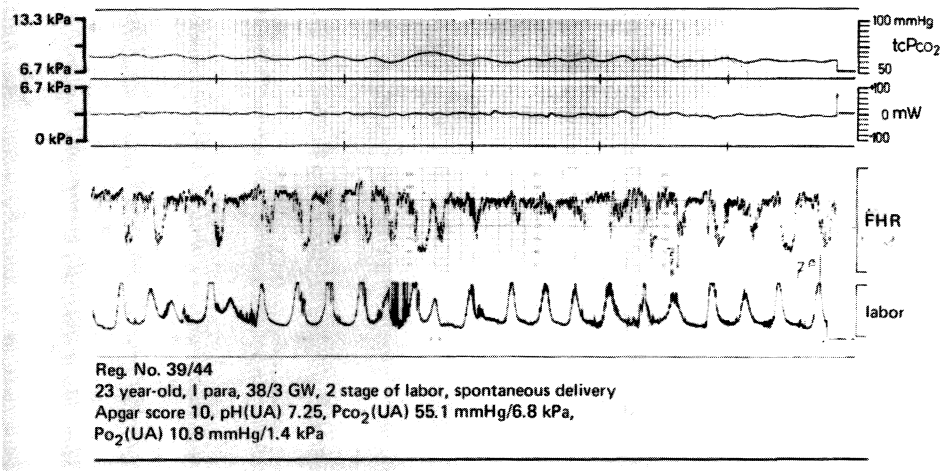

Fig. 5 Registration of $tcPco_2$ (mmHg), relative heat deviation (mW), fetal heart rate (FHR) and labour in a case where, in spite of abnormal heart rate pattern the $tcPco_2$ -level remained within the normal range.

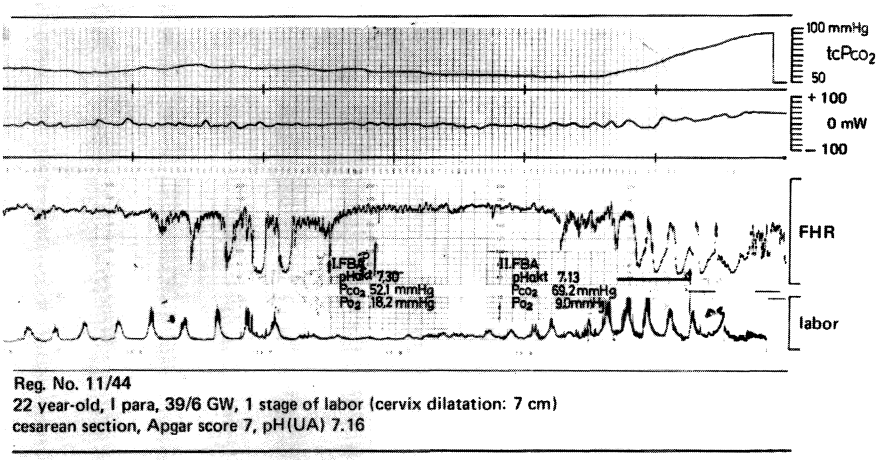

Fig. 6 Registration of $tcPco_2$ (mmHg), relative heat deviation (mW), fetal heart rate (FHR) and labour. Whilst the abnormal heart rate pattern at the beginning of this registration is misleading as neither the $tcPco_2$ values nor the values of the FBA I verify a disturbance, the moment of decompensation of the gas transfer is shown by a fast rise of $tcPco_2$ This complication was verified by fetal blood analysis (FBA II).

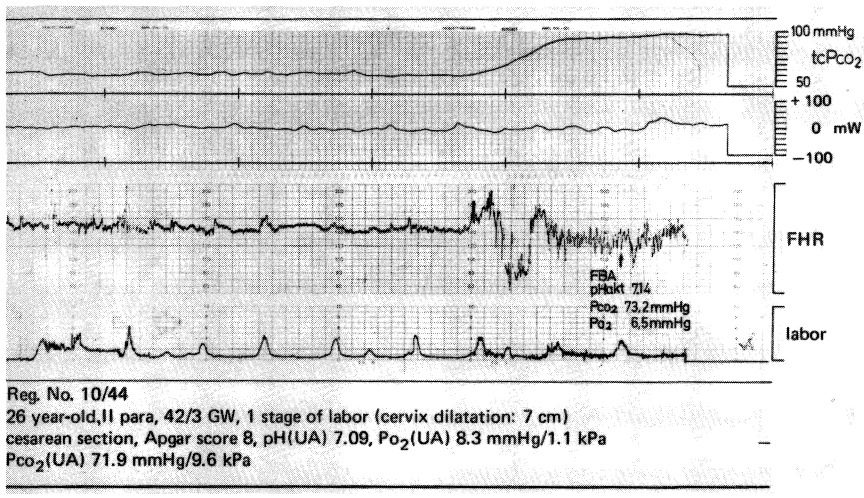

Fig. 7 Registration of $tcPco_2$ (mmHg), relative heat deviation (mW), fetal heart rate (FHR) and labour. In this case an acute intrauterine complication was more clearly indicated by the $tcPco_2$ -values than by the heart rate pattern.

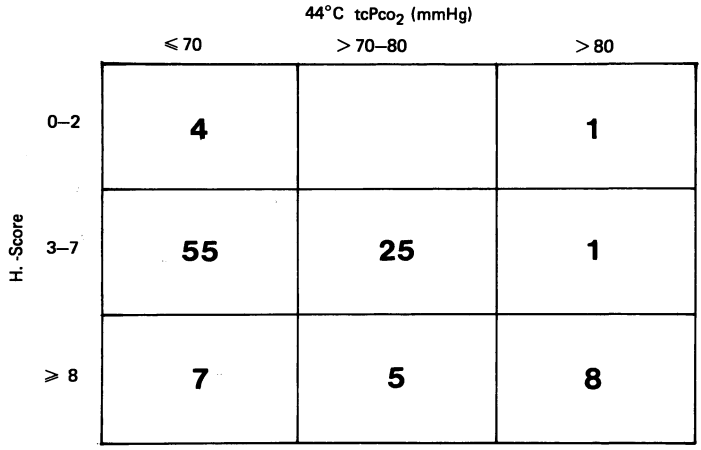

Fig. 8 Comparison between normal (≤ 70 mmHg), prepathologic (> 70-80) and pathologic (> 80) $tcPco_2$ values and normal (0 - 2), prepathologic (3 - 7) and pathologic (≥8) results of the Hammacher scoring system for the heart pattern (Hammacher 1974).

is more clearly indicated by the registration of the $tcPco_2$ than by the changes of the heart rate pattern. After an acceleration and a deceleration lasting only two and a half minutes, the heart rate returned to a normal value. The improved oscillation is additionally misleading, as it implicates a reestablished transplacental gas transfer. The continuous rise of the $tcPco_2$ level $>$ 80 mmHg clearly indicates a progressing distrubance. After verifying the acidosis by means of a fetal blood analysis also this baby was born by immediate cesarean section without signs of clinical depression, though the pH had further decreased to a value of 7.09.

The conformity respectively the discrepancy of the two methods was evaluated statistically by means of the chi-square test (Fig. 8). The evalutation of 53 hours of synchronous registration had a level of 30,90 for the chi-square test. 0,48 was calculated as the contingency coefficient according to Pearson. The quantitative evaluation demonstrates the superior specificity of $tcPco_2$ to indicate fetal distress as compared with the cardiotocographic tracing. When the CTG was pathologic the $tcPco_2$ was prepathologic or even normal in 60 %. When the CTG was prepathologic the $tcPco_2$ -level was within the normal range in 68 % of the cases.

Discussion

A considerable reduction of perinatal mortality and morbidity has been achieved by modern clinical methods of fetal surveillance. In spite of this fact, the clinical benefit of electronic fetal monitoring is still controversial (4, 11). The enormous rise of operative deliveries for fetal distress as the result of the introduction of continous fetal monitoring is the major objection of some authors against the general application of this technique (2, 11). The indication of fetal distress in cases where actually no complication emerges is the major shortcoming of the CTG when used as the only technique of supervision (3) The complementary use of a biochemical parameter has been proposed as an adequate solution. The fetal blood analysis is a reliable method to identify an intrauterine complication (6). This technique has the disadvantage of only providing intermittent information about the biochemical status of the fetus, and in some cases has to be repeated at short intervals if fetal heart rate patterns remain pathological. Additionally a traumatisation of the fetal skin in inevitable, as an incision has to be made in order to take blood samples.

The transcutaneous measurement of carbon dioxide ($tcPco_2$) with a heated Severinghaus electrode in the fetus during labour provides reliable information about one biochemical parameter (8). There is a considerable scattering of $tcPco_2$ values when the Pco_2 of the blood is raised during a disturbance of

the placental gas transfer. Such a phenomen can partly be explained by the fact that the electrochemical sensor traces the changes in the blood with considerable time lag and has been studied under defined condition in chronically instrumented pregnant sheep (9). By analysing the data of a clinical trial it was possible to define normal, prepathologic and pathologic values for the clinical use of the $tcPco_2$ in the fetus (8).

It should be mentioned that artefacts caused for example by a compression of the electrode or a caput succedaneum at the measuring site potentially result in raised $tcPco_2$ -levels in some cases (8). It thus seems to be advisable to confirm the intrauterine complication by the FBA technique. In this way it will also be possible to identify cases with only transient Pco_2 rise where no clinical intervention is necessary. Due to the good specificity of the $tcPco_2$ to indicate fetal distress it will be possible in the large majority of cases with suspicious, prepathologic and pathologic heart rate patterns to avoid unnecessary operative deliveries respectively the necessity to repreat fetal blood analysis. During this study the potential clinical benefit of the additional use of the $tcPco_2$ in cases where the cardiotocographic tracing indicated fetal distress was clearly approved. In spite of the fact that this clinical trial included cases with high risk of hypoxia, operative delivery for fetal distress was only performed in 12 % of the cases. On the other hand the $tcPco_2$ -recording informs and warns the obstetrician in the case of a disturbance of the gas transfer to the fetus occuring, even when the complication is not clearly indicated in the CTG. As the analysis of the data of this trial demonstrates, it will be possible to terminate labour early enough to avoid clinical manifestation of sub partu hypoxia. None of the babies of this trial were born in a clinically depressed state.

Hopefully the application of the $tcPco_2$ -electrode in the clinical surveillance of the fetus during labour will help to further improve the obstetrical management as it provides additional information in a non-traumatic and convenient way.

References

(1) Hammacher K, RB del Re, R Gaudenz, P De Grandi: Kardiotokographischer Nachweis einer fetalen Gefährdung mit einem CTG-Score. Gynäk Rdsch 14 (1974) 61

(2) Haverkamp AD, M Orleans, S Langendorfer, J McFee, J Murphy, HE Thomson: A controlled trial of the differential effects of intrapartum fetal monitoring. Am J Obstet Gynecol 134 (1979) 399

(3) Parer J: Benefits and detriments of fetal heart monitoring. Sem Perinat 2 (1978) 113
(4) Quilligan EJ, RH Paul: Fetal monitoring: is it worth it? Obstet Gynec 45 (1975) 96
(5) Saling E, KH Wulf: Zustandsdiagnostik beim Neugeborenen - Gruppeneinteilung. Fortsch Med 89 (1971) 12
(6) Saling E: Fetal scalp blood analysis. J Perinat Med 9 (1981) 165
(7) Schmidt S, K Langner, J Rothe, E Saling: A new combined non-invasive electrode for $tcPCO_2$-measurement and fetal heart rate recording. J Perinat Med 10 (1982) 297
(8) Schmidt S: Clinical trials on continuous measurement of fetal tcPCO. J Perinat Med 12 (1984) 241
(9) Schmidt S, K Langner, C Laiblin, JW Dudenhausen, J Gesche, E Saling: Ansprechzeit der tcPCO-Elektrode - eine tierexperimentelle Untersuchung. Biomed Tech 29 (1984) 289
(10) Severinghaus JW, M Stafford, AF Bradley: TcPCO electrode design, calibration and temperature gradient problems. Acta Anaesth Scand 68 (1978) 118
(11) Sykes GS, TM Molloy, P Johnson, JM Stirrat, AC Turnbull: Fetal distress and the condition of newborn infants. Br Med J 287 (1983) 943